Abstract

The ability to implement Wide Area Monitoring and Control in power systems is developing into a need in order to prevent wide scale cascading outages. Monitoring of events in the power system provides a great deal of insight into the behavior of the system. The research work presented in this thesis focused on two tools that aid in monitoring: State Estimation and Synchronized Phasors provided by Phasor Measurement Units (PMU).

State Estimation is essentially an on-line data processing scheme used to estimate the best possible state (i.e. voltage phasors) from a monitored set of measurements (active and reactive powers/voltage phasor measurements). The ever growing complexity and, developments in the state of art calls for robust state estimators that converge accurately and rapidly. Newton's method forms the basis for most of the solution approaches. For real-time application in modern power systems, the existing Newton-based state estimation algorithms are too fragile numerically. It is known that Newton's algorithm may fail to converge if the initial nominal point is far from the optimal point. Sometimes Newton's algorithm can converge to a local minima. Also Newton's step can fail to be a descent direction if the gain matrix is nearly singular or ill-conditioned.

This thesis proposes a new and more robust method that is based on linear programming and trust region techniques. The proposed formulation is suitable for Upper Bound Linear Programming. The formulation is first introduced and its convergence characteristics with the use of Upper Bound Linear Programming is studied. In the subsequent part, the solution to the same formulation is obtained using trust region algorithms. Proposed algorithms have been tested and compared with well known methods. The trust region method-based state estimator is found to be more reliable. This enhanced reliability justifies the additional time and computational effort required for its execution.

One of the key elements in the synchrophasor based wide area monitoring is the Phasor Measurement Unit. Synchronized real time phasor measurements over a distributed power network presents an excellent opportunity for major improvements in power system control and protection. Two of the most significant applications include state estimation and instability prediction.

In recent years, there has been a significant research activity on the problem of finding the suitable number of PMUs and their optimal locations. For State Estimation, such procedures, which are basically ensure observability based on network topology are sufficient. However for instability prediction, it is very essential that the PMUs are located such that important/vulnerable buses are also directly monitored.

In this thesis a method for optimal placement of PMUs, considering the vulnerable buses is developed. This method serves two purposes viz., identifying optimal locations for PMU (planning stage), and identifying the set PMUs to be closely monitored for instability prediction. The major issue is to identify the key buses when the angular and voltage stability prediction is taken into account. Integer Linear Programming technique with equality and inequality constraints is used to find out the optimal placement set. Further, various aspects of including the phasor measurements in state estimation algorithms are addressed.

Studies are carried out on various sample test systems, an IEEE 30-bus system and real life Indian southern grid equivalents of 24-bus system, 72-bus system and 205-bus system.